EXHIBIT B

Second Edition

HANDBOOK FOR PULP & PAPER TECHNOLOGISTS

Gary A. Smook

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Mr. Smook is prominent in the North American pulp and paper industry as the author of both HANDBOOK FOR PULP & PAPER TECHNOLOGISTS and HANDBOOK OF PULP AND PAPER TERMINOLOGY. He is also the author of over 30 papers on various aspects of kraft pulping, paper machine operation, technical management, and industrial training, and has contributed to three additional books. He has been awarded the Weldon Gold Medal (CPPA-TS, 1974) and TAPPI Fellowship (1987). He is a past chairman of the CPPA Professional Development Committee and is a current member of the Joint Textbook Committee of the Paper Industry.

Mr. Smook is a chemical engineering graduate from the University of California, Berkeley, and a registered professional engineer. He accepted his present teaching position in 1974 after a distinguished 18-year career in industry, and now divides his time between teaching, consulting and writing activities. His industrial consulting has focused on the areas of kraft mill process optimization, paper drying, technical information systems, and training seminars.

1.7 BEHAVIOR OF CELLULOSIC FIBERS

Cellulosic fibers exhibit a number of properties which fulfill the requirements of papermaking (summarized in Table 1-6). In general, the best balance of papermaking properties occurs when most of the lignin is removed from the fibers while retaining substantial amounts of hemicellulose. Properties are also greatly optimized by a mechanical treatment (e.g., **beating** or **refining**), which causes removal of the primary fiber walls and allows the fibers to hydrate (i.e., take water into the structure) and swell, increasing their flexibility and bonding power. The typical behavior of chemical pulp handsheet strength properties during beating is illustrated in Figure 1-10.

The **hydrophilic** nature of cellulosic fibers plays an important role because the papermaking process occurs in an aqueous medium. The fibers readily absorb water and are easily dispersed in a water suspension. When wet fibers are brought together during the sheet-forming operation, bonding is promoted by the polar attraction of the water molecules for each other and for the hydroxyl groups covering the cellulose surface. When water is evaporated from a formed sheet, the hydroxyl groups on opposing fiber surfaces ultimately link together by means of **hydrogen bonds** as shown in Figure 1-11.

TABLE 1-6. Properties of cellulosic fibers.

- high tensile strength
- suppleness (flexibility, conformability)
- resistance to plastic deformation
- water insoluble
- hydrophilic
- wide range of dimensions
- inherent bonding ability
- ability to absorb modifying additives
- chemically stable
- relatively colorless (white)

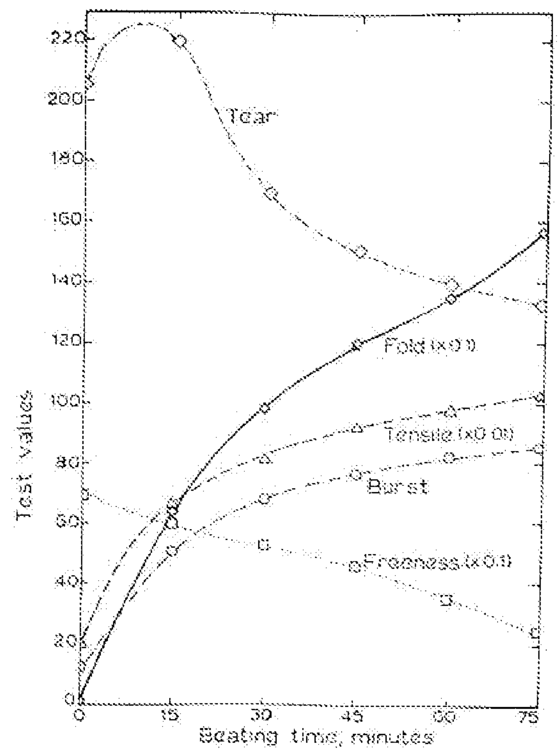

FIGURE 1-10. Typical response of softwood chemical pulp to laboratory beating.

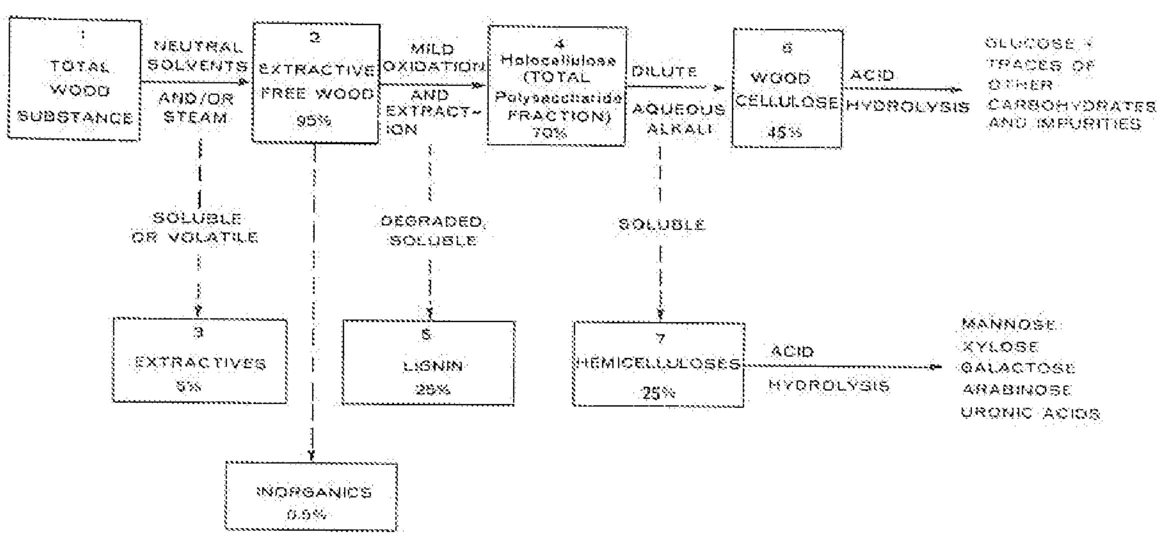

FIGURE 1-9. Schematic illustrating chemical separation of wood components (Bruley).

While individual cellulosic fibers generally have high tensile strength, the strength parameters of paper are more dependent on the bonds between fibers. Beating or refining tends to optimize bonding at the expense of individual fiber strength. Of course, the original fiber strength depends on the nature of the raw material and the method of pulping.

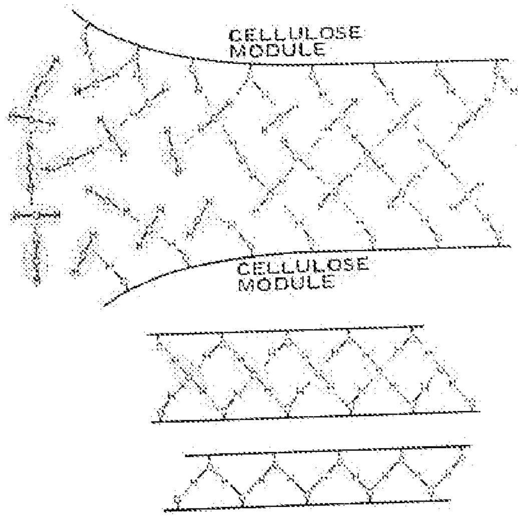

FIGURE 1-11. Illustrating different levels of hydrogen bonding:
(a) loosely through water molecules;
(b) more tightly through a monolayer of water molecules;
(c) directly.

Since **non-fibrous additives** are often used in the manufacture of paper products, the ability of the pulp fibers to retain a wide variety of modifying materials during sheet-forming operations is important. Filtration, chemical bonding, colloidal phenomena, and adsorption are involved in the retention of particles. Filtration is suitable for larger particles, but other mechanisms are more important for retaining smaller particles and colloids. Retention is enhanced by flocculation or precipitation of the insoluble material and by optimal adjustment of the electrokinetic charges within the system. The ability to absorb or adsorb soluble additives is dependent on the relative chemical "affinity" of the pulp fibers.

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